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SOMMAIRE

Un facteur important qui influence le comportement du calfeutrage à l'extérieur des bâtiments est le mouvement provoqué par les changements de température journaliers et annuels. Bien que le calfeutrage lui-même se dilate et se contracte avec la température, ces changements dimensionnels sont peu importants et sont grandement neutralisés par les changements dans les éléments dans le bâtiment qui entourent le joint. Actuellement, les fabricants de matériaux de calfeutrage suggèrent que pour les calfeutrages de meilleures qualités, les joints devraient être conçus d'une largeur telle que le mouvement provoqué par les éléments du bâtiment qui l'entoure ne sera pas plus ± 25 pour cent la largeur du joint. Le cadre d'exposition décrit ici produit diverses quantités de mouvement couvrant une gamme qui dépasse 25 pour cent. Le mouvement en cycle du cadre est produit par les changements de conditions de température qui provoquent différents montants de mouvements dans deux sortes de métaux utilisés pour la construction du cadre.

Weathering Rack for Sealants

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An important factor influencing sealant performance on the outside of buildings is the cyclic movement induced by daily and yearly temperature changes. Although the sealant itself expands and contracts with temperature, these dimensional changes are negligible and largely reversed by changes in the building elements surrounding the joint. At the present time sealant manufacturers suggest that for the best quality sealants, joints should be designed with such width that the movement produced in them by the surrounding building elements will not be more than ±25% of the joint width. The exposure rack here described produces various amounts of movement covering a range reaching beyond 25%.

The cyclic movement of the rack is produced by changes in weather conditions that induce different amounts of movement in two kinds of metal used in the construction of the rack.

KEY WORDS: Aluminum; Temperature change; Sealant; Concrete; Thermocouples; Gauges; Temperature difference; Exposure.

INTRODUCTION

The performance concept of testing and evaluating building materials implies that a given material has been subjected to either actual or simulated conditions of service and that its behavior with time is predictable in relation to criteria of acceptable performance.

Laboratory testing to characterize the mechanical capability of each class of sealant (silicones and two-part polysulphides) has now been developed to a considerable degree by the Division of Building Research.[1-4] Similarly, the actual movements of various types of joints in buildings have been measured to give information regarding the rates of strain and elongation or compression to which sealants may be subjected in service.[1,5] What is yet unknown is sealant behavior under cyclical movement and simultaneous temperature changes, where the specimen is subjected to compression at high temperature and extension at low temperature while undergoing normal aging conditions. A testing facility designated as a weathering rack was therefore designed and constructed to permit a study of the behavior of sealants under simulated conditions of service. This paper gives its details of design and presents an assessment of its operation.

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DESCRIPTION

Figure 1 shows the sealant weathering rack. It is 41 ft (12.5 m) long and 3.5 ft (1.1 m) wide and can accommodate 216 specimens of the same dimensions as are used for testing to CGSB specifications: a sealant bead of 0.5 × 0.5 × 2 in. (1.3 × 1.3 × 5.0 cm) between substrate bars of 0.5 × 1 × 3 in. (1.3 × 2.5 × 7.6 cm). Various substrates can be used, but that shown is aluminum. A close-up of the center portion of the rack can be seen in *Figure* 2.

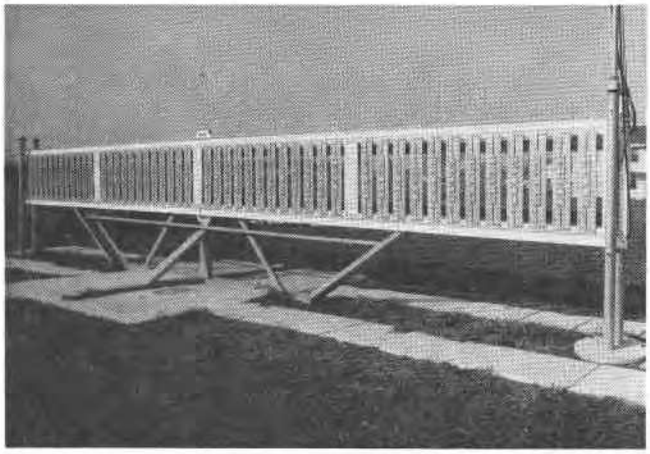

Figure 1 — Sealant weathering rack

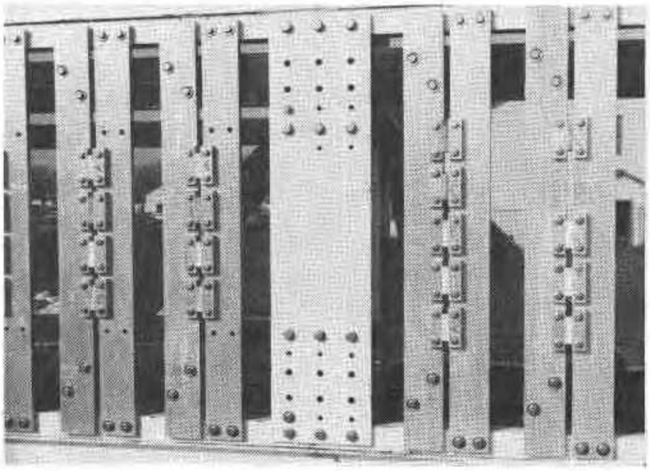

Figure 2 — Close-up of center portion of rack

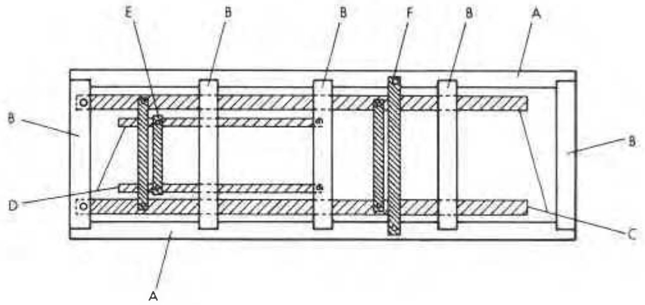

Figure 3 — Schematic representation of the working principle of the weathering rack

The rack undergoes cyclic movements in response to temperature changes, utilizing the difference in the thermal coefficient of expansion between steel and aluminum. *Figure* 3 is a schematic drawing showing how the differential thermal movement is applied. At the top and bottom of the rack steel bars (A) are joined by five vertical steel plates (B) painted white. Two double 2 × 2 in. (5 × 5 cm) aluminum bars (C) run the full length, attached only on the left side so that they are free to move, guided by steel cylinders behind the vertical steel plates. Another pair of single 2 × 2 in. aluminum bars (D) are attached to the central steel plate, free to expand along their full length in the direction opposite the expansion of the longer bars (C). As ambient temperature changes, the steel and aluminum components of the frame expand and contract by different amounts. At any vertical cross-section of the assembly the relative movement between the steel frame and the aluminum bars is determined by the difference of the thermal coefficients of linear expansion and the lengths of metals contributing to the movement. In order to utilize the differential movement, pairs of vertical aluminum plates (not painted) are attached to the steel or to the aluminum bars. Because the specimens are bolted to these vertical plates (*Figures* 2 and 4) the differential movement is transmitted to the sealant bead.

Load produced by straining the sealant specimens is transmitted to the horizontal steel and aluminum members. Their cross-sectional area had to be made as large as was practical so that strain in the members would not seriously reduce differential movement.

From the point of view of operation, the rack can be divided into two areas. In *Figure* 1, all the specimens in the first quarter (left) receive cyclic movements with identical amplitude; but on the remaining area of the rack, the amplitude increases progressively from the left to right for each pair of vertical plates. This results from the different ways of attaching the vertical aluminum plates in the different areas (*Figure* 3). In the first quarter of the rack, one of the plates (E) is bolted to the short aluminum bars and in the remaining three quarters, to the steel frame (F). The second pair of plates is always attached to the long aluminum bars (C). As a result, in the first quarter two different types of aluminum bars move in opposite directions with temperature change, being bolted separately at opposite ends to the same steel frame. Consequently, the total length of steel and aluminum bars affecting the movement is constant for any location in this area, resulting in the same movement for all the specimens.

In the remaining area of the rack where the long aluminum bars are attached to the vertical steel end plates only at one end, the length of metals to be taken into consideration when calculating movement increases from left to right for each pair of vertical aluminum plates. The amount of movement at a given point can be estimated from the coefficient difference, the total length from the left end of the rack, and the temperature difference.

The weight of the structure is carried by two V-shaped legs resting on a one-piece concrete slab. The supporting elements are anchored to the concrete slab by bolts cast in the concrete. The vertical tubing at each end of the frame guides movement and prevents bending during strong winds (*Figure* 1).

Movement occurring on the rack was determined by joint movement gauges described in reference (1). The corresponding temperature readings were taken by means of thermocouples fastened with adhesive to the surface of both the aluminum and the steel bars on the side facing south. The correlation between movement of the rack and temperature readings was statistically analyzed. The results are given in *Table* 1, and *Figure* 5 illustrates the plot obtained with one of the gauges.

Three gauges were used for taking movement readings: No. 1 was located in the first quarter of the

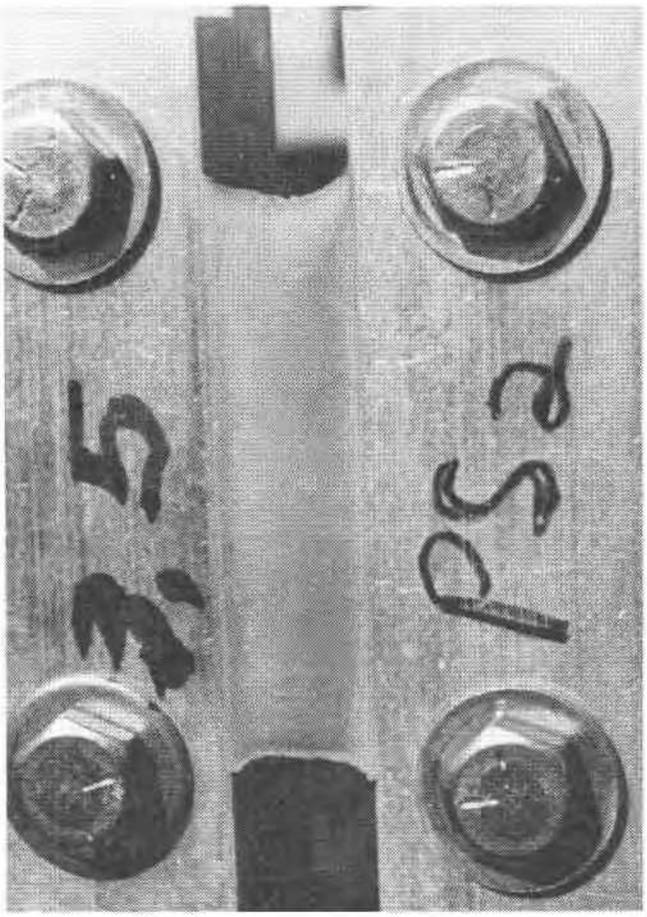

Figure 4 — Specimen attached to vertical plates

Table 1 — Statistical Evaluation of Cyclic Movements At Various Positions on the Rack

Gauge	No. 1	No. 2	No. 3
Location (left to right on *Figure* 1)	Column 6	Column 30	Column 43
Correlation coefficient	–0.966	–0.979	–0.934
Slope of best fitting line			
in./F	–0.00108	–0.00143	–0.00210
cm/C	–0.00486	–0.00644	–0.00945
Standard error of slope			
in./F	0.00001	0.00002	0.00002
cm/C	0.00005	0.00009	0.00009
Observed movement (calculated from slope)	±13.1%	±17.3%	±25.4%
Movement estimated from thermal coefficient	±18.5%	±23.1%	±33.4%

rack where there is a constant amplitude of the cyclic movement for 12 pairs of vertical aluminum plates; No. 2 was placed at the 30th pair of plates; and No. 3 at the 43rd pair. The readings now reported cover a period of a full year, from the end of November 1974. They were taken once every working day for the first four months to confirm the smooth operation of the rack. Afterwards, the frequency of readings was reduced to two per week. Each consisted of a maximum, a minimum, and a reset gauge value and the corresponding minimum, maximum, and reset temperature readings, where the gauge readings are taken in inches, and indicate the position of one side of the joint in relation to the other. From this one can derive the width change the sealant specimens undergo.

Because a maximum temperature produces a minimum width on the specimens, and vice versa, they are correlated and plotted in this manner. These are extreme readings that occur during the time interval between two observations. The reset readings are taken immediately after the extreme readings, when the gauge is reset to start a new interval of observation. (For further details about the operation of the gauges see reference (1)). The various types of readings are illustrated with different symbols in *Figure* 5. The three lines are the result of statistical analysis: the outer two are the 95% confidence limits, the centerline being the best fitting line of the data. It is the best fitting line that calibrates the rack movement, and its slope is the length change per degree temperature change. When multiplied by temperature difference for one year they give the total yearly movement.

Statistical analysis was carried out with readings of all three movement gauges, using the observed temperature for both the aluminum and steel bars which were painted black and white, respectively. The maximum temperature difference readings of aluminum were 3.5°F (1.9°C) and the minimum temperatures 0.2°F (0.1°C) higher on the average than those of steel, with standard deviation of the differences 2.3°F (1.3°C) and 0.9°F (0.5°C), respectively. The above values did not change significantly when the data were divided into winter and summer readings and analyzed separately.

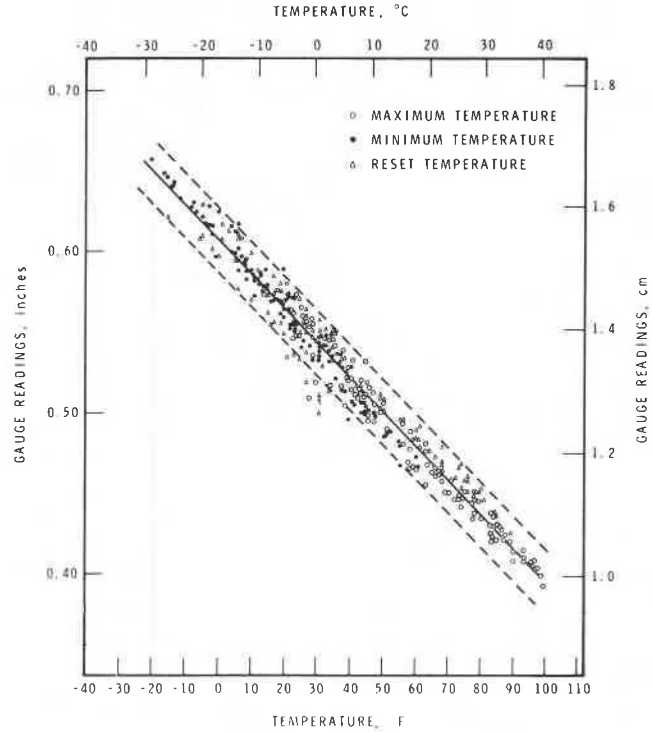

Figure 5 — Weathering rack movement at gauge No. 3 vs. aluminum temperature

The difference in temperature of the two bars is not large enough to justify considering them separately.

Table 1 presents the summary of the analysis using temperatures for aluminum only. Correlation between rack movement and temperature is good, as may be seen from the values obtained for the correlation coefficients. The slope of the best fitting line for the data can be used to calculate movement occurring on the rack at the location of each particular gauge. The reliability of the values obtained for the slopes is confirmed by their small standard error.

Maximum yearly movement is calculated by multiplying the value of the slope by the yearly temperature difference (121°F, or 67.2°C) and converting it to the percentage of the specimen width. As can be seen from *Table* 1, the maximum movement at gauge No. 1 is ±13%. This movement applies to all specimens exposed in this section of the rack, and increases from the 13th pair of vertical plates to the last, the 48th; it is ±17% at gauge No. 2 and ±25% at gauge No. 3. Movement at any position can be calculated from these findings. One can also estimate movement from the coefficients of linear expansion. As *Table* 1 shows, the estimated movements are considerably higher than the observed movements, indicating restraint, which can be partly attributed to the load that the sealant specimens exert on the bars and partly to friction.

SUMMARY

An outdoor sealant weathering rack was built on which exposed standard sealant specimens underwent the natural aging process experienced by exterior sur-

faces of buildings. This includes physicochemical changes induced by radiation, temperature changes, the effect of air and moisture, and by the movement to which joints are subjects. This movement, produced by using the differential thermal movement between steel and aluminum, was measured with gauges at three locations on the rack. One quarter of the total rack area produced identical maximum movements on the specimens, ±13% per year; the remaining area produced from about ±9 to ±30% in 36 steps. Restraints prevented the attainment of movement estimated from the thermal expansion coefficient of the metals, partly due to the load imposed by the specimens and partly to friction.

Two types of observations can be obtained from this rack: on the area that gives constant yearly movements one can evaluate relative fatigue performance of a large number of specimens; on the remaining three quarters of the area, with movement increasing in small increments, one can observe the ultimate movement a sealant can safely tolerate, i.e., the movement capability of a sealant.

Various types of sealants have already been exposed and observations of their behavior will be reported later. □

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